Shock

Shock is defined as **a syndrome of impaired tissue perfusion accompanied by hypotension**. This impairment of tissue perfusion eventually leads to **cellular dysfunction**, followed by **organ damage and death** if untreated.

Causes of shock are situations that result in:

- Reduction of intravascular volume (hypovolemic shock),
- Increased vascular capacitance (distributive shock): Shock characterized by overt loss of vascular tone causing acute tissue hypoperfusion. Numerous events (e.g., anaphylaxis, neurogenic causes, sepsis) can initiate distributive shock. **Septic shock** is characterized by a profound vasodilatory response and resultant decrease in blood pressure.
- Myocardial pump failure (cardiogenic shock): Shock arising primarily from an abnormality of cardiac function (either mechanical or nonmechanical in nature) where there is an inability to maintain cardiac output (CO) unrelated to hypovolemia.
    1. **Nonmechanical causes:** Acute myocardial infarction, Low cardiac output syndrome, Right ventricular infarction, End-stage cardiomyopathy
    2. **Mechanical causes:** Rupture of septum, Mitral or aortic insufficiency, Papillary muscle rupture or dysfunction, Critical aortic stenosis, Pericardial tamponade

Pathophysiology

Shock results in failure of the circulatory system to deliver sufficient oxygen (O_2) to tissues despite normal or reduced O_2 consumption. Although the etiology of shock is varied, the **eventual progression (if untreated)** results from a common pathway of **ischemia**, **endogenous inflammatory cytokine** release, and the **generation of oxygen radicals**. When cells are subjected to a **prolonged period** of ischemia, anaerobic metabolism begins. Severe metabolic lactic acidosis often develops secondary to tissue ischemia and causes localized vasodilation, which further exacerbates the impaired cardiovascular state. Additionally, lactic acidosis can alter mitochondrial function and eventually result in cell death. In the advanced stages of shock, irreversible cellular damage leads to multiple organ system failure, also known as multiple organ dysfunction syndrome. Fall in blood pressure (BP) is compensated by increased sympathetic outflow, activation of the renin–angiotensin system, and other factors that stimulate peripheral vasoconstriction. Compensatory vasoconstriction redistributes blood away from skin, skeletal muscles, kidneys, and gastrointestinal (GI) tract toward vital organs (eg, heart and brain) in attempt to maintain oxygenation, nutrition, and organ function.

Hypovolemic Shock

Shock secondary to a reduction in intravascular volume. The overall result is reduced venous return and decreased CO. The severity of hypovolemic shock depends on the amount and rate of intravascular volume loss and each person's capacity for compensation. Although responses vary, a healthy person may tolerate an acute loss of as much as 30% of his or her intravascular volume with minimal clinical signs and symptoms. Compensatory mechanisms such as increases in HR, myocardial contractility, and SVR, are sufficiently effective for this loss in volume such that measurable falls in systolic BP are not detected. Losses in excess of 80% generally overwhelm compensatory mechanisms and the patient's condition can deteriorate to overt shock with hypotension and signs of hypoperfusion. If restorative measures are not taken immediately, irreversible shock and death may result. **The most common cause of hypovolemic shock** is:

1. **hemorrhagic shock** in which intravascular volume depletion occurs as a result of bleeding. Trauma is responsible for most cases of acute hemorrhagic shock; other significant causes are rupture of vascular aneurysms, acute gastrointestinal bleeding, ruptured ectopic pregnancy, and postoperative bleeding.

2. **Non-hemorrhagic** in which intravascular volume depletion occurs as a result of: (a) excess fluid losses from gastrointestinal sources or (b) plasma loss caused by burns or sequestration (also known as third-space accumulation).

CLINICAL PRESENTATION

Patients with hypovolemic shock may have thirst, anxiousness, weakness, lightheadedness, dizziness, scanty urine output, and dark yellow urine. Signs of more severe volume loss include tachycardia (>120 beats/min), tachypnea (>30 breaths/min), hypotension (SBP <90 mm Hg), mental status changes or unconsciousness, agitation, and normal or low body temperature (in the absence of infection) with cold extremities.

Diagnosis

Evaluation of past medical history, clinical presentation, and laboratory findings are key components in establishing the diagnosis. **Lab data for hypovolemic shock:**

- Serum sodium and chloride concentrations are usually high with acute volume depletion.

- The blood urea nitrogen (BUN): creatinine ratio may be elevated initially, but the creatinine increases with renal dysfunction.
- Metabolic acidosis results in elevated lactate conc. With decreased bicarbonate and pH.
- In hemorrhagic shock, the red cell count, hemoglobin, and hematocrit will decrease.

Treatment

Supplemental O2 should be initiated at the earliest signs of shock, beginning with 4 to 6 L/min via nasal cannula or 6 to 10 L/min by face mask. Once an adequate airway is established and initial vital signs are obtained, the most important therapeutic intervention is the infusion of IV fluids. Initially, crystalloids or colloids are used to restore blood volume as blood products may not be immediately available and are frequently unnecessary to manage mild shock (10%–20% blood loss).

IV fluids

Initial fluid resuscitation consists of isotonic crystalloid (0.9% sodium chloride or lactated Ringer solution), colloid (5% albumin and dextran), or whole blood.

Effectiveness of crystalloids

Crystalloids are **isotonic solutions** that contain either saline (0.9% sodium chloride; "normal saline") or a saline equivalent (lactated Ringer's [LR] solution). Isotonic crystalloid solutions freely distribute within the extracellular fluid compartment, which is divided between the interstitial and intravascular spaces at a ratio of 3:1. So this mean large volume of crystalloid fluid is required to expand the intravascular space during resuscitation. However, they have the advantage of correcting the deficit of fluids not only in the intravascular but also in the interstitium. **Ringer's solution is the fluid of choice** for the initial resuscitation of trauma patients and **normal saline as the second choice**. Because normal saline has a high chloride content (45 mEq more than LR), it can cause hyperchloremic acidosis, thereby worsening the tissue acidosis that occurs in the setting of hypovolemic shock.

Effectiveness of colloids

Colloidal solutions contain **large oncotically active** molecules that are effectively expand the intravascular space with little loss into the interstitium since intact capillary membranes are relatively impermeable to colloids. Thus, smaller volumes of colloids than of crystalloids are thus required for

resuscitation, and because these large molecules persist intravascularly, their duration of action is longer.

Albumin

Albumin is available as a 5% solution which used for volume expansion and it is isotonic with the plasma and a 25% solution that is hypertonic which is used for hypoproteinemia. It may cause anaphylactic reaction. On infusion, 5% albumin increases plasma volume by approximately half the volume infused, with an initial duration of action of 16 hours.

Hydroxyethyl starch has comparable plasma expansion to 5% albumin solution but is usually less expensive.

Dextran 40, dextran 70, and **dextran 75** are available for use as plasma expanders. These solutions are not used as often as albumin or hetastarch for plasma expansion, possibly due to concerns related to anaphylaxis, which is more likely to occur with the higher molecular weight solutions.

A safe and effective approach is giving 1 to 2 L of fluid as an initial bolus as rapidly as possible for an adult or 20 mL/kg for a pediatric patient. Additional fluid boluses may be necessary, depending on the patient's response. Between boluses, fluids are slowed to maintenance rates (150–200 mL/hour), with ongoing evaluation of the patient's physiologic response for signs of continued blood loss or inadequate perfusion that would indicate the need for additional volume replacement. Indications that **circulation is improving** include normalization of BP, pulse pressure, and HR. signs that **actual organ perfusion** is normalizing and that fluid resuscitation is adequate include improvements in mental status, warmth and color of skin, improved acid-base balance, and increased urinary output. The minimal acceptable urine output for a patient is 0.5 mL/kg. **Persistent metabolic acidosis** in a normothermic shock patient usually indicates the need for additional fluid resuscitation; sodium bicarbonate is not recommended unless the pH is <7.2.

Blood Replacement

The prior conventional approach to the transfusion of critically ill patients was to maintain the hemoglobin above 10 g/dL or the hematocrit above 30%. In acute hemorrhage, the actual degree of blood loss is not accurately reflected by the hemoglobin and hematocrit values, because it takes at least 24 hours for all fluid compartments to come to equilibrium, a normal hematocrit (or Hgb concentration) in the setting of hemorrhagic shock does not rule out significant blood loss or indicate adequacy of transfusion. Only when equilibrium has been

reached can these measures be used reliably to gauge blood loss. Patients who require blood transfusion are:

- Trauma patients who have acute bleeding
- Patients who are not acutely bleeding and who do not respond to initial volume resuscitation or who transiently respond but remain tachycardic, tachypneic, and oliguric will likely require blood transfusion.

Complication of blood transfusion

Electrolyte abnormalities, hemolytic reactions, transmission of infectious disease, coagulopathies (because transfused blood does not contain platelets because platelets do not survive at the temperatures required for red blood cell storage). Banked blood is stored with a citrate anticoagulant additive, with multiple transfusions, the large amount of citrate can cause hypocalcemia and acid– base abnormalities. Hyperkalemia also can occur because transfusion of stored blood causes the release of potassium from hemolyzed (ruptured) red blood cells. Coagulation problems are primarily associated with low levels of clotting factors in stored blood, as well as dilution of endogenous clotting factors and platelets following administration of the blood. As a result, a coagulation panel (PT, international normalized ratio, and aPTT) should be checked in patients undergoing replacement of 50% to 100% of blood volume in 12 to 24 hours.

Other blood products

Packed red blood cells: contain hemoglobin that increases the O2- carrying capacity of blood, thereby increasing O2 delivery to tissues. This is a function not performed by crystalloids or colloids. Packed red cells are usually indicated in patients with continued deterioration after volume replacement.

Fresh frozen plasma replaces clotting factors. It is indicated if there is ongoing hemorrhage in patients with a prothrombin time (PT) or activated partial thromboplastin time (aPTT) >1.5 times normal, severe hepatic disease, or other bleeding disorders. fresh-frozen plasma (containing all clotting factors).

Cryoprecipitate and **factor VIII** are generally not indicated in acute hemorrhage but may be used once specific deficiencies have been identified. Cryoprecipitate (containing factor VIII and fibrinogen).

Distributive shock

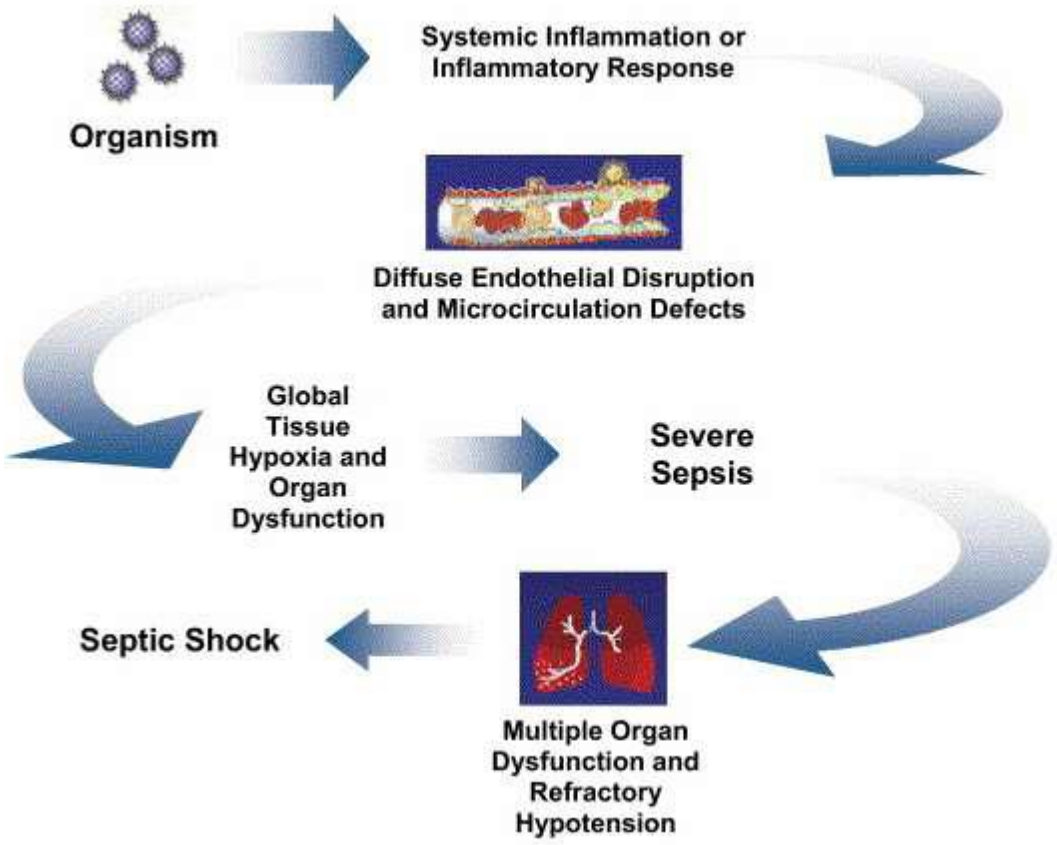
Septic shock

Sepsis syndrome: a systemic inflammatory response resulting from infection. When associated organ dysfunction, hypoperfusion, or hypotension is present, it is termed severe sepsis; when hypotension persists despite adequate fluid resuscitation and requires inotropic or vasopressor support, it is termed septic shock. Immunocompromised patients, neonate, AIDS, cancer patients, DM, alcoholics, those with renal or hepatic failure are at high risk for septic shock.

Etiology

Systemic infection caused by either aerobic or anaerobic bacteria is the leading cause of septic shock. Fungal, protozoal, or viral infections can also be encountered but it is rare. However, Gram negative bacteria like *Enterobacteriaceae, Pseudomonas,* and *Haemophilus,* responsible for septic shock slightly more than G+ bacteria.

Pathophysiology



Clinical signs: hyperthermia**,** tachycardia**,** low blood pressure (SBP<90) **and** mental status changes

Characteristic laboratory findings include leukocytosis, thrombocytopenia with or without coagulation abnormalities, and hyperbilirubinemia. Also, CRP is highly elevated. These features are usually readily detectable and occur within 24 hours after bacteremia develops, particularly if the bacteremia is caused by gram-negative organisms.

Therapeutic Approach of septic shock:

The management of septic shock is directed toward three primary areas:

(a) Eradication of the source of infection,

(b) Hemodynamic support and control of tissue hypoxia, and

(c) Inhibition or attenuation of the initiators and mediators of sepsis.

Additional issues should be considered like glucose control, and stress ulcer prophylaxis.

Blood glucose management should occur with insulin when 2 consecutive blood glucose levels are >180mg/dL.

DVT prophylaxis: done using subcutaneous LMWH, if creatinine clearance is less than 30ml/min then use dalteparin.

Stress ulcer prophylaxis using H2 blocker or proton pump inhibitor be given to patients with severe sepsis/septic shock who have bleeding risk factors.

A. **Eradicating the source of infection** involves the early administration of antimicrobial therapy, and, if indicated, surgical drainage. The use of an appropriate antibiotic regimen is associated with a significant increase in survival. Recommended empiric regimens typically include an anti pseudomonal penicillin or third- or fourth-generation cephalosporin plus vancomycin or a similar broad-spectrum agent to cover for gram positive cocci, aerobic gram-negative bacilli, and anaerobes. Duration of therapy is typically 7 to 10 days; longer courses may be appropriate in patients who have undrainable foci of infection, bacteremia with S. aureus; or if patient has neutropenia. However, when combination therapy used empirically it should not be administered for longer than 3 to 5 days.

B. **Hemodynamic support during septic shock treatment:** Firstly, start with IV fluids, then check MAP if it is below the goal, check PCWP (Pulmonary capillary **wedge** pressure) if within the range continue fluids but if PCWP = 18 or

more then use vasopressor or inotropes: use either norepinephrine 0.02 – 3 mcg/kg/min or dopamine at 2 – 20 mcg / kg /min. Crystalloids are preferred but albumin can be used when patients require substantial amounts of crystalloids. Usually crystalloids are given as 500 – 1000ml/30min as bolus doses.

Inotropes and Vasopressors

Norepinephrine was found to be superior to dopamine, with improvement in arterial BP, urine flow, oxygen delivery in to the tissues and lactate levels. Dopamine as an alternative vasopressor agent to norepinephrine only in patients with bradycardia. Dopamine is an appropriate choice if MAP, CO and SVR low because of its combined α-adrenergic vasoconstrictive actions and β-adrenergic inotropic effects will increase SVR and CO, and thus MAP. **Dobutamine** produces a larger increase in CO and is less arrhythmogenic than dopamine.

Vasopressin

Sepsis can cause a decrease in responsiveness to catecholamines resulting in refractory hypotension, possibly because of down regulation of adrenergic receptors. Vasopressin is an endogenous hormone that has very little effect on BP under normal conditions, but becomes very important in maintaining BP when the baroreceptor reflex is impaired, such as in shock states. However, vasopressin is not recommended as a replacement for norepinephrine or dopamine in patients with septic shock but may be considered in patients who are refractory to catecholamine vasopressors despite adequate fluid resuscitation.